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ABSTRACT

Selected electromyographic parameters underlying static postural control in 4, 6, and 8 year old normally and slowly developing children during performance of selected arm movements were studied. Developmental delays in balance control were assessed by the Cashin Test of Motor Development (1974) and/or the Williams Gross Motor Coordination Test Battery (1973). Twenty-four normally developing and six motorically awkward children performed three different static balance tasks, in three different conditions, while eight different muscle groups were monitored electromyographically. Normally developing children displayed little or no difference in the amount of muscular activity involved in postural control with or without a superimposed weighted arm movement. Slowly developing children exhibited higher levels of muscular activity in maintaining postural control when weighted arm movements were superimposed than when they were not. The average level of muscular activity observed in static postural task performance decreased with age for normally developing children, while there was no consistent relationship between age and level of muscular activity for slowly developing children. The implications of these findings are discussed in relationship to working with slowly developing children in motor control. (Author/JD)

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A DEVELOPMENTAL STUDY OF STATIC POSTURAL CONTROL AND SUPERIMPOSED ARM MOVEMENTS IN NORMAL AND SLOWLY DEVELOPING CHILDREN

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An Abstract of

A DEVELOPMENTAL STUDY OF STATIC POSTURAL CONTROL AND SUPERIMPOSED ARM MOVEMENTS IN NORMAL AND SLOWLY DEVELOPING CHILDREN

Janet M. Fisher

The purpose of the present study was to investigate selected electromyographic parameters underlying static postural control in 4, 6, and 8 year old normally and slowly developing children during performance of selected arm movements. Developmental delays in balance control were assessed by The Cashin Test of Motor Development (1974) and/or The Williams Gross Motor Coordination Test Battery (1973). Twenty-four normally developing and six motorically awkward children performed three different static balance tasks, in three different conditions, while eight different muscle groups were monitored electromyographically. Results indicated that normally developing children displayed little or no difference in the amount of muscular activity involved in postural control with or without a superimposed weighted arm movement. Slowly developing children exhibited higher levels of muscular

activity in maintaining postural control when weighted arm movements were superimposed than when they were not. Normally developing children displayed lower levels of muscular activity than slowly developing children at all chronological ages. In general the average level of muscular activity observed in static postural task performance decreased with age for normally developing children, while there was no consistent relationship between age and level of muscular activity for slowly developing children. Results of this study suggest that there are major differences between normally developing and slowly developing children in performance of static postural tasks both with and without superimposed weighted arm movements. The implications of these findings are discussed in relationship to working with slowly developing children in motor control.

INTRODUCTION

Volitional movements involve complex patterns of excitation and inhibition of muscle groups. Muscular contractions associated with voluntary movements must be accurately organized spatially and temporally if movements are to be skillful and efficient. Sport skill practitioners have long observed important differences between skilled and unskilled performers in the amount of extraneous movement involved in the performance of complex motor tasks. Such observations have been supported by electromyographic research which has shown that unskilled performers usually display higher levels of muscular activity in non-contributing muscle groups than do skilled performers.

In one such study, Anderson (1979) provided electromyographic evidence that showed higher levels of muscular activity in unskilled individuals performing an overarm throw and a tennis serve. She also found that skilled individuals displayed more precise patterns of muscular excitation and relaxation than did unskilled individuals in performing these common sport tasks. Payton and Kelley

(1972) used electromyographic procedures and found that when a person was performing an unfamiliar novel throwing task, the muscles under study showed significantly less total electrical activity during skillful than unskillful movements. Hobart and Vorro (1976) found electromyographic differences between men and women during the learning of a novel throwing skill. Of interest was the greater difference in total electrical activity of antagonist muscles in women during the entire testing period. Herman (1970) demonstrated electromyographically that during motor skill acquisition there is a constant refinement in the level of muscle tension. Herman suggested that this helps to produce stabilization of movement and a reduction in movement error. Kamon and Gormley (1968) demonstrated a patterning of muscle actions which they interpreted as "improvements in coordination" during learning of a horizontal bar exercise. They compared prelearning and postlearning EMG records and noted that the duration of muscular activity involved in performance decreased with learning. They also noted a reduction in the amount of overlapping EMG recordings of the actions of several different muscles. Finley, Wirta, and Cody (1967) provided electromyographic evidence of motor learning in the form of increased amplitude of muscular activity and increased use of prime movers in selected motions at the elbow joint. Chapman and Troup (1969) found no consistent

change in levels of muscular activity as a result of training on the erector spinae muscle. Previous research studies have indicated that important neuromuscular changes or differences in muscular activity are reflected in differences in electromyograms.

In order to be successful, voluntary movements must be accompanied by certain subcortically controlled adjustments in posture. As the demands of the motor task vary, postural adjustments which contribute to the efficiency of task performance automatically take place. Such postural adjustments occur primarily in the musculature of the head and trunk and are most readily evidenced in their role in the performance of gross motor tasks where maintenance of the body's center of gravity over a changing base of support is integral to performance. Thus, automatic postural adjustments are requisite to efficient performance of such skills as throwing, kicking, skipping, and hopping, etc. (Espenschade, 1953).

Lawrence and Kuypers (1968) demonstrated the significance of postural control in skilled voluntary movements of monkeys. These authors created subcortical lesions which disrupted postual control of muscles of the trunk and shoulder girdle. This resulted in poor discrete localized movements of the distal musculature. That is, without postural control mechanisms intact, discrete localized movements could not be performed. Individuals

afflicted with certain neuromuscular diseases (e.g., cerebral palsy) in which postural reactions are malfunctioning cannot execute controlled movements of the extremities efficiently (Abelmasova et al., 1974; Kenney & Heaberlin, 1962). In addition, a characteristic common to developmentally delayed and/or motorically awkward children is their obvious lack of precise postural or balance control. These observations clearly suggest that subcortical postural adjustments are an important part of the neurophysiological mechanism which underlies motor coordination in that they provide the foundation upon which a vast repertoire of motor acts can be built.

Initially the child begins to develop postural control in the head and trunk; this is followed by acquisition of the ability to roll over. Next the child accomplishes an unsupported sit, and finally he masters the skills of standing and walking. Studies by Simard (1969) and Rosenbloom and Horton (1971) report that with increasing age, normal children develop the ability to localize appropriate muscle activity required for optimal neuromuscular control. Shambes' (1976) electromyographic investigation of motor control in balance tasks involving upper and lower extremity support of the trunk provides further insight into the development of this neurophysiological mechanism. The results of this study indicate that 8 year olds tended to use fewer muscles, to display

more defined localization of muscular activity, and to show smaller amplitudes of electrical activity in various muscle groups during maintenance of static balance positions than 4 year olds. Four year old children seemed in general to be unable to suppress extraneous muscular activity in performing static balance tasks. Bachman (1961) and Keogh (1965) reported that, at a behavioral level, children develop increasingly greater mastery over static balance tasks between the ages of 6 and 11. These data suggest that a less mature postural mechanisms may exist in the younger child.

In a recent electromyographic study of static postural control in 4, 6, and 8 year old normally and slowly developing children (i.e., a clinical population of motorically awkward children), Williams, Fisher, and Tritschler (1980) found dramatic differences in the use of various muscle groups by children when they performed different balance tasks. These authors reported a consistent developmental trend of decreasing muscular activity with increasing age in normally developing children. Overall, slowly developing children displayed greater amplitudes of muscular activity than normally developing children of the same chronological age. This difference was observed at all ages studied and became increasingly more clearcut with age. When muscle activity profiles (the amplitudes of EMG activity in several muscle groups) of slowly

developing children and normally developing children were compared, there was little or no similarity among any of the age groups. That is, the specific muscle groups involved in performance of various static postural tasks and the amplitude of activity in those muscle groups was different for children of different ages and developmental levels.

Little or no information is available regarding the nature of postural reactions of children when a discrete arm or limb movement is superimposed on a given postural framework. In many common daily activities and sport skills a child is required to manipulate a variety of objects while continuing to maintain postural control, i.e., he holds and manipulates a ball, a racket, a bat. It is also not clear how static postural control of normally developing children differs from that of motorically awkward children when limb movements are superimposed upon a specific postural framework. The purpose of the present study was to investigate selected electromyographic parameters underlying postural control in 4, 6, and 8 year old normally developing and motorically awkward children during the performance of selected arm movements.

Research Hypotheses

The research hypotheses for the present investigation were as follows·

1. There will be no difference in the amount of muscular activity involved in static postural control with or without a superimposed weighted arm movement in normally developing children;

2. Motorically awkward children will display greater amounts of muscular activity in maintaining static postural control when a weighted arm movement is superimposed on this framework than when it is not;

3. When a weighted arm movement is superimposed upon a static balance position, motorically awkward children will display greater amounts of muscular activity than normally developing children of the same chronological age; and

4. When a weighted arm movement is superimposed upon a static balance position, the amount of muscular activity in muscle groups involved in maintaining this postural framework will decrease with age in normally developing children; no similar trend will be observed in motorically awkward children.

METHODS

Subjects

The participants in the study were 30 children, 4, 6, and 8 years old. Twenty-four of the children had no identifiable motor or balance deficiencies as assessed by The Cashin Test of Motor Development (1974) and/or The Williams Gross Motor Coordination Test Battery (1973). These children maintained balance with eyes open for over 24 seconds ($\bar{x}$ = 24.45) and with eyes closed for over 16 seconds ($\bar{x}$ = 16.40). This group was labeled as normally developing children (NDC). Included in this group were eight 4 year olds (seven males and one female), eight 6 year olds (all males), and eight 8 year olds (seven males and one female). The remaining six male subjects, two from each age group were deemed motorically awkward children with identified static balance deficiencies. The developmental delays in balance control were assessed by The Cashin Test of Motor Development (1974) and/or The Williams Gross Motor Coordination Test Battery (1973). These children maintained balance on one foot with eyes open for approximately 5 seconds ($\bar{x}$ = 5.08 and with eyes

closed for less than 3 seconds ($\bar{x}$ = 2.80). These children were labeled as slowly developing children (SDC).

Tasks

All children were asked to perform three different static balance tasks. These tasks were selected from those described by Shambes (1976) and included the erect stand, full kneel, and half kneel positions (see Appendix A). Each child performed these tasks for 30 seconds in each of three different conditions. The unweighted condition involved performance of the static postural task with no arm movement. The weighted 1# and weighted 2# conditions involved performance of the static postural task with a superimposed arm movement while holding either a 1 lb. or 2 lb. weight in the non-preferred hand. In the weighted conditions the child held the weight in the hand for 5 seconds; on the command, "Up", the child raised the weighted arm to a position of 90° abduction at the shoulder joint (see Appendix B). This position was held for approximately 20 seconds. On the command, "Down", the child moved the arm back to its resting position (0° abduction). This position was held for 5 seconds. The sequence in which the tasks were performed was the same for all children.

Electromyographic Procedures

Muscular activity was monitored on a 14-channel electromyograph. The muscles chosen for monitoring were those which are believed to contribute to the maintenance of posture or anti-gravity effort (Shambes, 1976). The muscles monitored for the three balance tasks in the present study were m. trapezius lower, m. posterior deltoid, m. pectoralis major, m. erector spinae, m. rectus abdominus, m. gastrocnemius, m. soleus, and m. semitendinosus. Beckman bipolar surface electrodes were secured over the bellies of the muscles on the preferred side. Palpation techniques described by Brunnstrom (1972) were used to determine appropriate electrode placement. The proximal electrode was placed over the belly of the designated muscle; the second electrode was placed 2.0 cm distally in line with the muscle fibers. A ground electrode was secured slightly superior to the lateral malleolus of the right leg. Eight channels of a 14-channel ink writing physiograph were used to record muscle activity. Physiograph sensitivity was adjusted so as to maintain the EMG signals going into the recorder to less than one volt maximum. Paper speed was 15 mm per second.

General Procedures

Each child was tested individually in the presence of at least one parent. All children were shown the testing area and the equipment to be used and were given time

to become familiar with the testing apparatus. The postural tasks were described to the child, and he then practiced each task. When the child felt comfortable and ready to begin, muscles were palpated and electrodes secured. The child performed the selected balance tasks in the following order: unweighted-stand, stand with 1 lb. weight, stand with 2 lb. weight, unweighted-full kneel, full kneel with 1 lb. weight, full kneel with 2 lb. weight, unweighted-half kneel, half kneel with 1 lb. weight, and half kneel with 2 lb. weight. The testing procedure, from electrode placement to task completion, took approximately 30 minutes per child.

RESULTS

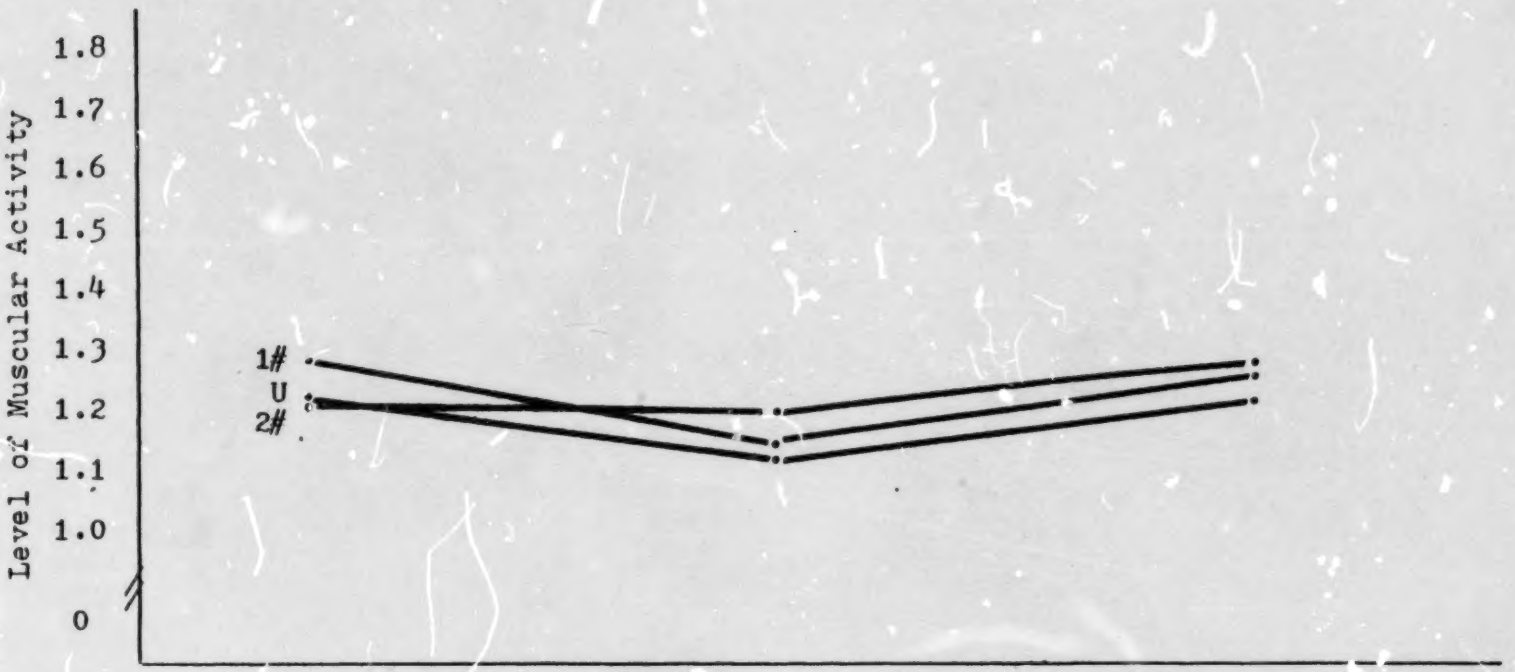
For purposes of analysis, EMG activity recorded in selected muscle groups during performance of each static postural task was quantified according to a 5 level classification system. The lowest level of muscular activity represented amplitude displacements of .2 cm or 20 uv. This was coded level 1 and assigned a score of 1. Level 2 represented amplitude displacements of .3 cm or 30 uv. Levels 3, 4, and 5 respectively represented amplitude displacements of .5 cm, .7 cm, and .9 cm with corresponding electrical recordings of 50 uv, 70 uv, and 90 uv. Electromyographic recordings which were confounded by electrocardiograph input, observed as regularly spaced heart beat deflections, were eliminated from the classification system.

Four readings were taken on each muscle group for each task. Two readings were taken early during the 30 second balance period, at 2 and 4 seconds after the "go" signal; two readings were taken late in the balance period, at 2 and 4 seconds prior to the "stop" signal for the unweighted task conditions. In the weighted conditions readings were taken at 2 and 4 seconds into the upward and

downward movement phases. The average of these four readings across all tasks was the dependent variable and was used as an indicator of the general level of muscular activity present in a given muscle group during performance of static postural tasks with or without movement. Means were labeled as follows: unweighted (U), performance of the static postural task with no arm movement; weighted 1# (1#), performance of the static postural task with a superimposed arm movement using a 1 lb. weight; and weighted 2# (#), performance of the static postural task with a superimposed arm movement using a 2 lb. weight. Means were plotted as a function of level of development (normally developing and slowly developing), as a function of age (4, 6, and 8 years old), and as a function of age X level of development. Standard deviations and standard errors of the means are given at the bottom of each figure. Group differences based on standard errors of the means are also given at the bottom of each figure. Underscoring with a continuous line, e.g., U 1# 2#, indicates overlapping standard errors of the means.

Level of Development

The mean level of muscular activity observed during static postural task performances by normally developing children is shown in Figure 1. The average level of muscular activity observed ranged from 1.143 (unweighted-



	$\bar{x}$	s.d.	s.e.		$\bar{x}$	s.d.	s.e.		$\bar{x}$	s.d.	s.e.
Stand	1.232	.248	.036	Kneel	1.143	.167	.024	½Kneel	1.238	.205	.030
Stand 1#	1.273	.222	.032	Kneel 1#	1.156	.197	.028	½Kneel 1#	1.264	.209	.030
Stand 2#	1.224	.210	.030	Kneel 2#	1.206	.185	.027	½Kneel 2#	1.277	.179	.026

Conclusion: 2# U 1# Conclusion: U 1# 2# Conclusion: U 1# 2#

Figure 1. Mean amplitude of muscular activity for static postural tasks: normally developing children.

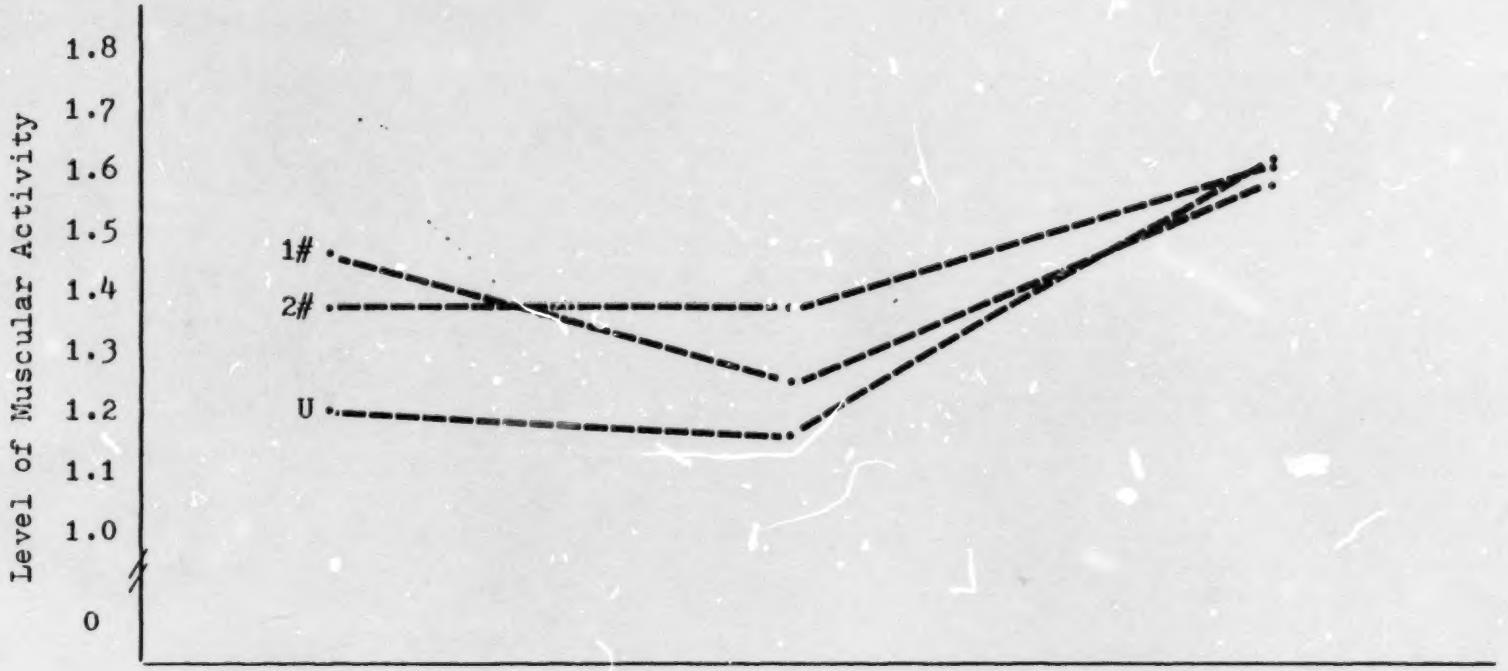
full kneel) to 1.277 (half kneel with 2 lb. weighted arm movement). In general, with age groups combined, normally developing children displayed little or no difference in the amount of muscular activity involved in postural control with or without a superimposed weighted arm movement. In addition, the level of muscular activity observed in the unweighted condition was similar whether the child was standing or in full or half kneel positions. In fact, for standing and half kneel positions the amount of muscular activity observed was nearly identical for all conditions (i.e., whether or not a weighted arm movement was superimposed). Only for the 2 lb. weighted arm movement in the full kneel position was there evidence of a statistical difference in the level of activity in muscles involved in static postural control (full kneel, $\bar{x}$ = 1.143; full kneel 2#, $\bar{x}$ = 1.206).

Variability in the amount of muscular activity seen in normal children's performance of static postural tasks was minimal. Standard deviations ranged from .167 (unweighted-full kneel) to .210 (stand with 2 lb. weight). Interestingly, variability of muscular activity observed in postural task performance was greater when the child was in a standing position than in either full or half kneel positions. Variability was least in the full kneel position.

The mean level of muscular activity for static postural task performances by slowly developing children is shown in Figure 2. The average level of muscular activity ranged from 1.158 (unweighted-full kneel) to 1.602 (unweighted-half kneel). Slowly developing children as a whole exhibited higher levels of muscular activity when superimposed weighted arm movements were involved in static postural task performance than when they were not. This was true for both the stand and full kneel positions. In the half kneel position, however, the level of muscular activity observed was similar for all conditions. The levels of muscular activity in this condition were also elevated in comparison to the other two positions.

Variability in muscular activity levels observed in slowly developing children's performances of the static postural tasks ranged from .209 (full kneel with 1 lb. weight) to .397 (unweighted-half kneel). The amount of muscular activity observed in static postural task performance was much more variable when the child was in the half kneel position than when he was in either the stand or full kneel positions. Variability of performance for these two positions was generally comparable.

A comparison of average level of muscular activity for normally and slowly developing children clearly indicated that slowly developing children displayed consistently higher levels of muscular activity during static



	$\bar{x}$	s.d.	s.e.		$\bar{x}$	s.d.	s.e.		$\bar{x}$	s.d.	s.e.
Stand	1.200	.280	.081	Kneel	1.158	.274	.079	½Kneel	1.602	.397	.115
Stand 1#	1.460	.270	.078	Kneel 1#	1.254	.209	.060	½Kneel 1#	1.574	.331	.095
Stand 2#	1.374	.252	.073	Kneel 2#	1.360	.303	.087	½Kneel 2#	1.600	.234	.068

Conclusion: U 2# 1# Conclusion: U 1# 2# Conclusion: 1# 2# U

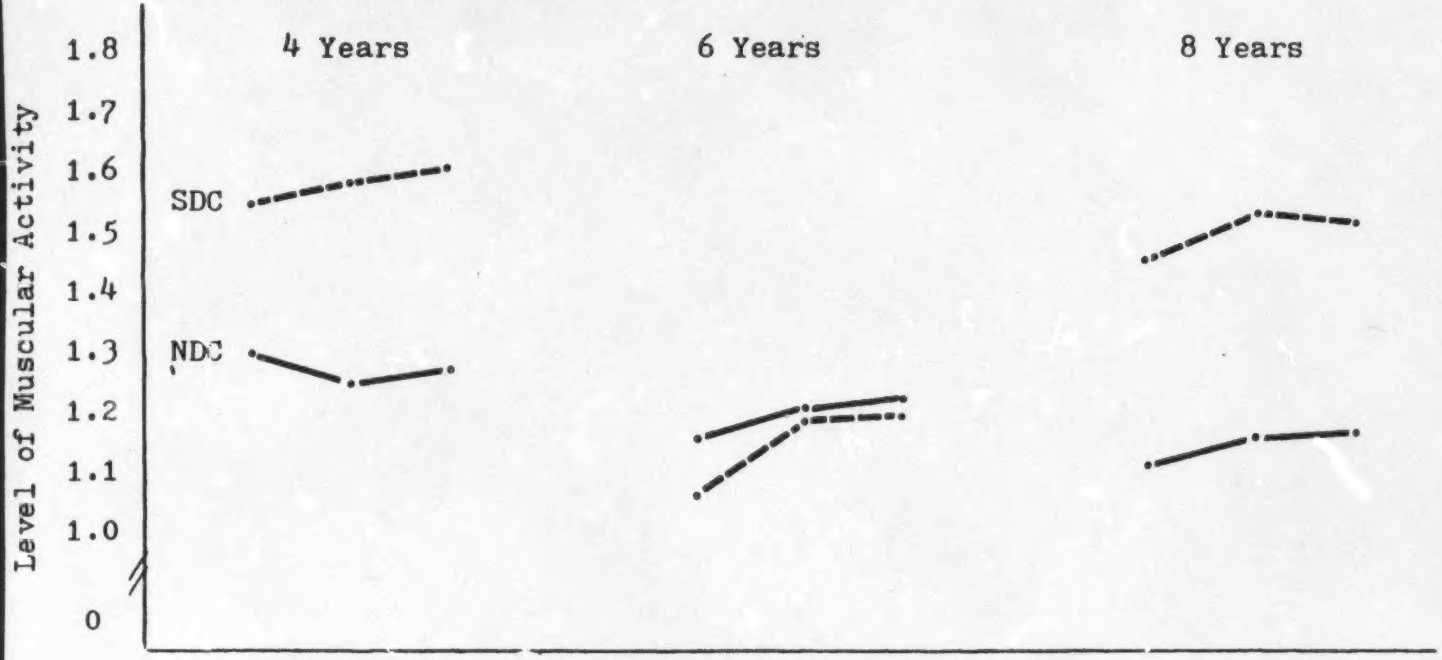
Figure 2. Mean amplitude of muscular activity for static postural tasks: slowly developing children.

postural task performance than normally developing children. This was true for all weighted and unweighted conditions except the unweighted stand. In this one instance normally developing children exhibited a slightly higher mean level of muscular activity (NDC $\bar{x}$ = 1.232 and SDC $\bar{x}$ = 1.200). Slowly developing children were also more variable than normally developing children in the amount of muscular activity observed in performance of static postural tasks with or without superimposed weighted arm movements.

Age and Age X Level of Development

The mean level of muscular activity for static postural task performances for normally and slowly developing children as a function of age is given in Figure 3. In general the average level of muscular activity observed in static postural task performance decreased with age for normally developing children. Muscular activity in 4 year old normally developing children was greater than that for 6 year olds; similarly, muscular activity levels were greater for 6 year old normally developing children than for 8 year olds. The relationship between levels of muscular activity and age existed for all positions and all task conditions for normally developing children.

The trend of decreasing amplitude of muscular activity with increasing age observed for normally developing children was not present in slowly developing children.



		4 Years			6 Years			8 Years		
		U	1#	2#	U	1#	2#	U	1#	2#
NDC	$\bar{x}$	1.302	1.266	1.270	1.185	1.249	1.255	1.137	1.193	1.200
	s.d.	.131	.115	.106	.133	.155	.162	.130	.182	.163
	s.e.	.033	.029	.026	.033	.039	.040	.033	.041	.041
SDC	$\bar{x}$	1.553	1.593	1.624	1.078	1.219	1.235	1.449	1.549	1.542
	s.d.	.287	.208	.098	.009	.081	.132	.073	.061	.079
	s.e.	.144	.104	.049	.005	.040	.066	.037	.030	.040
Conclusion:		U_{NDC} U_{SDC}			U_{NDC} U_{SDC}			U_{NDC} U_{SDC}		
		$1\#_{NDC}$ $1\#_{SDC}$			$1\#_{NDC}$ $1\#_{SDC}$			$1\#_{NDC}$ $1\#_{SDC}$		
		$2\#_{NDC}$ $2\#_{SDC}$			$2\#_{NDC}$ $2\#_{SDC}$			$2\#_{NDC}$ $2\#_{SDC}$		

Figure 3. Mean amplitude of muscular activity for static postural tasks by 4, 6, and 8 year olds: normal and slowly developing children.

There was no consistent relationship between age and level of muscular activity for slowly developing children. Muscular activity involved in static postural control in 4 year old slowly developing children was greater than for 6 or 8 year old slowly developing children. However, 8 year olds exhibited higher levels of muscular activity than 6 year olds.

Differences between normal and slowly developing children existed at all age levels. Discrepancies between groups were greatest, however, for 4 and 8 year olds. Both 4 and 8 year old slowly developing children displayed measurably higher levels of muscular activity in all tasks than did normally developing children of the same chronological age. In contrast, 6 year old slowly developing children exhibited slightly lower levels of muscular activity in all task conditions than did 6 year old normally developing children. Only in the unweighted static postural task condition, however, was this difference reliable.

Variability of muscular activity amplitude scores of 6 and 8 year old normally developing children tended to be slightly greater than that of slowly developing children of the same chronological age. Four year old slowly developing children, however, were more variable than 4 year old normal children.

DISCUSSION

In general, slowly developing children displayed consistently higher levels of muscular activity during static postural performance than did normally developing children. This was true for all positions and conditions except for the erect standing position where no arm movement was superimposed. These observations suggest that slowly developing children had more difficulty than normally developing children in performing all except the most highly automated postural tasks (e.g., standing erect). It would appear that the development of postural control was not as refined for slowly developing as for normally developing children. Williams et al. (1980) also reported that slowly developing children displayed higher levels of muscular activity during performance of static postural tasks than did normally developing children. Since the methodology and subject groups used in both the present study and the Williams et al. (1980) study were similar, the two studies together provide strong support for the notion that motorically awkward children exhibit higher levels of muscular activity during static postural task

performance than do normally developing children. These differences in muscular activity levels of normal and slowly developing children during performance of comparable tasks are consistent with Basmajian's (1977) theory of motor skill learning. Basmajian (1977) suggests that motor learning, whether it involves the unconscious processess of a child learning simple motor responses or the more complex skill learning of athletes, requires the progressive inhibition of extraneous muscles that flood into play when one initially attempts to produce a designated motor response. Slowly developing children in this study invariably demonstrated excessive muscular activity in static postural control. It may be that the process of learning to inhibit muscular activity unnecessary and/or unproductive to task requirements is slower in these children. Consistent with the finding for normally developing children are the results of studies by Kamon and Gormley (1968) and Payton and Kelley (1972). In these studies total electrical muscular activity decreased among adolescent and adult populations as performance improved across practice trials. The tasks for these studies, respectively, were a gymnastic stunt and a novel ball toss.

In addition to being higher for slowly developing children, muscular activity amplitude scores were also more variable for this group of children. This was true across all positions and conditions of task performance.

This finding mirrors that of Williams et al. (1980) who also found 4, 6, and 8 year old slowly developing children to be consistently more variable than normally developing children in static postural task performance. Variability was greatest in the half kneel task and smallest in the full kneel task. In the half kneel where level and variability of muscle activity were very high, other signs of "extraneous" motor activity were also visibly observable. Slowly developing children displayed postural rigidity, facial tension, and periodic swaying of the body accompanied by movement of the extremities. When the standing and full kneel tasks were performed, overt signs of this nature were not readily observable. The half kneel position was clearly the most difficult for slowly developing children, for these children had to be manually assisted in the positioning of their limbs each time the half kneel position was assumed. The standing the full kneel positions were easily assumed by these children upon verbal command.

As hypothesized, muscular activity decreased with increasing age in normally developing children in all positions and task conditions. This finding is consistent with data reported by Shambes (1976) and Williams et al. (1980). Williams et al. (1980) found a decrease in muscular activity level with increasing chronological age in normally developing children. Shambes (1976) studied 4

and 8 year old normally developing children and found that older children demonstrated higher degrees of motor control in performance of static balance tasks involving both upper and lower extremity support of the trunk. She reported that 8 year olds displayed less postural sway, lower levels of muscular activity, and higher degrees of localization of muscular activity than younger children. Overall EMG parameters reported in these three studies support the notion that with increasing age there is a trend in normally developing children toward lower levels of muscular activity within muscle groups involved in performance of static balance tasks. Postural control is apparently a process which undergoes considerable change during the years from 4 to 8. It is not yet clear from this or other studies whether postural control of this kind plateaus at the age of 8 or continues to undergo further refinement as growth proceeds. Behavioral data provided by Bachman (1961), Espenschade (1953), and Keogh (1965) suggest that balance skills continue to improve from 6 to 11 years of age. If these two measures of balance performance are related, they would suggest that EMG parameters continue to show some change and refinement beyond the eighth year.

As was predicted, slowly developing children did not exhibit an identifiable age-related pattern of decreasing muscular activity with concomitant increases in age. Not only were levels of muscular activity higher in slowly

developing children than in normally developing children of similar chronological ages, there was also no evidence of any differences between 8 year olds and 4 year olds in level of muscular activity involved in static postural control. Eight year old slowly developing children were, however, less variable as a group than 4 year olds. It is commonly accepted that as normal children mature they gain greater and greater control over the large muscle masses of the body. Data from the present study would indicate that this may not be totally true for slowly developing children. The slowly developing child, unlike the normally developing child, does not appear to follow an age-related pattern of steadily improving muscular control but rather shows evidence of little or no change in muscular activity involved in selected motor responses. In a sense, slowly developing children seem to be like less proficient sports performers in that their motor performance is characterized, regardless of age, by the presence of excessive levels of muscular activity (Anderson, 1979; Herman, 1970; Payton & Kelley, 1972).

The EMG characteristics of 6 year old slowly developing children in this study were inconsistent with those observed for 4 and 8 year old slowly developing children. They were also markedly different from those of 6 year old slowly developing children reported by Williams et al. (1980). Six year old slowly developing children in the

present study displayed considerably lower levels of muscular activity than either 4 or 8 year old slowly developing children. It is interesting to note that in the weighted arm movement conditions they displayed muscular amplitude levels comparable to those of normally developing 6 year olds. These observations may, of course, be due to the small number of slowly developing 6 year olds studied (n = 2).

As proposed, normally developing children displayed little or no difference in level of muscular activity with or without superimposed weighted arm movements. The static postural tasks and superimposed weighted arm movements used in this study were relatively simple, and normally developing children seemed to have mastered the ability to move a single limb in a simple movement without upsetting static postural control. Kenney and Heaberlin (1962) also report that normally developing children (of unspecified ages) were able to perform specified isotonic muscle contractions equally well with and without resistance. The EMG patterns of children in this study were essentially identical whether the contraction occurred with or without resistance.

In the present study, slowly developing children exhibited higher levels of muscular activity while maintaining static postural control when there was a superimposed weighted arm movement than when there was not. These observations suggest that slowly developing children have

not developed the ability to superimpose an independent arm movement on a static postural framework without additional neuromuscular adjustment being necessary. Although the foregoing was true for the erect stand and full kneel positions it was not observed in the half kneel. In the half kneel position, the average level of muscular activity for both the arm movement and no arm movement conditions was similar and higher than that seen in the erect stand and full kneel positions. Slowly developing children may have been so challenged by the balance requirements of the half kneel position that the addition of the arm movement added no further demand. It is also possible that in the half kneel position, the body weight was not equalized across the total base of support. Many slowly developing children seemed to use a smaller base of support in this position, concentrating the weight primarily on the forward leg. Thus, the arm movement may have in fact acted as a kind of stabilizer for the smaller base of support. It is important to note that levels of muscular activity were slightly lower in the half kneel position when there was a superimposed arm movement than when there was not.

Kenney and Heaberlin (1962) studied agonist and antagonist muscle patterns in cerebral palsied children and reported that numerous neuromuscular adjustments had to occur before controlled movements were possible for these children. For the cerebral palsied children there

was no difference between the electromyograms for various isotonic contractions performed with or without resistance. They did, however, display motor discharges in agonist muscles that were "massive" or "explosive". Antagonist muscles also became active quickly and with enough power to hinder the intended task. In general, the pattern of orderly, sequential, and controlled muscular responses that were observed in normal children was not found in the cerebral palsied children.

The final point of interest is that for both groups of children there was essentially no difference in static postural control when arm movements involved a 1 lb. versus a 2 lb. weight. For motorically awkward children the weighted arm movement conditions were more difficult than the unweighted condition in the stand and full kneel positions. The 2 lb. weighted movement apparently created no further control demands than did the 1 lb. weighted movement. Kenney and Heaberlin (1962) found that when normal children were challenged by "considerable resistance" to movement (although they do not specify the exact amount) that it became increasingly more difficult to distinguish between the EMG patterns of normal and cerebral palsied children.

In conclusion, results of this study clearly suggest that there are major differences between normally developing and slowly developing children in performance

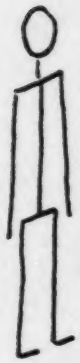
of static postural tasks both with and without superimposed weighted arm movements. Although it is not clear why slowly developing children have not developed as efficient static postural control as normally developing children, comparison of the two groups across ages indicates that slowly developing children are not simply lagging behind normally developing children in their neuromuscular development. It would appear that they are in fact following a different pattern of development. A common approach to working with motorically awkward children is to provide them with activities developmentally appropriate for younger normal children. It may be that techniques used in working with slowly developing children need to be distinctly different and uniquely designed for that kind of child. For example, to improve static postural control in slowly developing children, one might need to use a combination of biofeedback techniques and physical practice. Through the use of visual and auditory feedback from EMG recordings, other researchers have shown remarkable improvements in the performance of atypical populations (Amato, Hermsmeyer, & Kleinman, 1973; Hughes et al., 1979; Middaugh & Miller, 1980). It is possible that slowly developing children can learn, through the use of similar techniques, to inhibit extraneous muscular activity and to control and localize the amount of prductive muscular activity during performance of static postural tasks.

Another implication of the present study deals with the effects of superimposing a weighted arm movement upon a static postural framework. One to two pound weights seemingly "unbalance" the postural framework for slowly developing children. Perhaps greater care should be taken in the selection of weighted implements (balls, bats, rackets, etc.) for use with slowly developing children in both clinical and recreational settings. Such a consideration may be of lesser concern for normally developing children unless the weights of implements are excessive.

The EMG data provided by this study cannot conclusively support or contradict the behavioral balance data by Bachman (1961), Espenschade (1953), and Keogh (1965) which suggests that balance skills continue to improve from 6 to 11 years of age. A suggestion for further study is to extend the age groups studied within the present electromyographic experimental design. Such an investigation would help to determine the age at which normally developing children typically plateau in their static postural task performance. Of particular importance is the need to correlate behavioral balance assessments with electromyographic data. It is possible that EMG measures of postural control may be more sensitive than behavioral measures of skill, and would thus help to identify at earlier ages potential problems in the development of postural control.

APPENDIX A

Static Postural Positions



Erect Stand

Full Kneel

Half Kneel

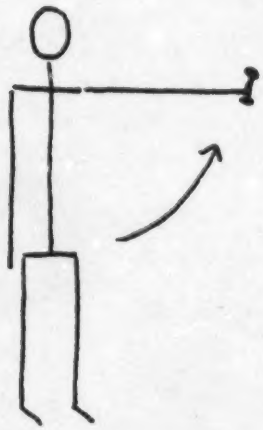
Erect Stand: A normal, relaxed, upright posture with feet comfortably apart and arms at sides.

Full Kneel: Bent knees, legs slightly apart with the thighs, trunk, and head in a vertical line directly over the knees; toes of feet straight (i.e., not turned under).

Half Kneel: Dominant leg flexed 90° at the hip, knee, and ankle; thigh of non-dominant leg in vertical alignment with trunk and head.

APPENDIX B

Sample Static Postural Position with Superimposed Weighted Arm Movement



Erect Stand with Superimposed Weighted Arm Movement

APPENDIX C

Mean Amplitude of Muscular Activity for Static Postural Tasks: Normally Developing Children

	$\bar{x}$	s.d.	s.e.
Stand	1.232	.248	.036
Stand 1#	1.273	.222	.032
Stand 2#	1.224	.210	.030
	Conclusion:	2# U 1#	
Kneel	1.143	.167	.024
Kneel 1#	1.156	.197	.028
Kneel 2#	1.206	.185	.027
	Conclusion:	U 1# 2#	
½ Kneel	1.238	.205	.030
½ Kneel 1#	1.264	.209	.030
½ Kneel 2#	1.277	.179	.026
	Conclusion:	U 1# 2#	

APPENDIX D

Mean Amplitude of Muscular Activity for Static Postural Tasks: Slowly Developing Children

	$\bar{x}$	s.d.	s.e.
Stand	1.200	.280	.081
Stand 1#	1.460	.270	.078
Stand 2#	1.374	.252	.073
	Conclusion: U 2# 1#		
Kneel	1.158	.274	.079
Kneel 1#	1.254	.209	.060
Kneel 2#	1.360	.303	.087
	Conclusion: U 1# 2#		
½ Kneel	1.602	.397	.115
½ Kneel 1#	1.574	.331	.095
½ Kneel 2#	1.600	.234	.068
	Conclusion: 1# 2# U		

APPENDIX E

Mean Amplitude of Muscular Activity for Static Postural Tasks by 4, 6, and 8 Year Olds: Normal and Slowly Developing Children

4 Years

		U	1#	2#
NDC	$\bar{x}$	1.302	1.266	1.270
	s.d.	.131	.115	.106
	s.e.	.033	.029	.026
SDC	$\bar{x}$	1.553	1.593	1.624
	s.d.	.287	.208	.098
	s.e.	.144	.104	.049

Conclusion: U_{NDC} U_{SDC}
$1\#_{NDC}$ $1\#_{SDC}$
$2\#_{NDC}$ $2\#_{SDC}$

6 Years

NDC	$\bar{x}$	1.185	1.249	1.255
	s.d.	.133	.155	.162
	s.e.	.033	.039	.040
SDC	$\bar{x}$	1.078	1.219	1.235
	s.d.	.009	.081	.132
	s.e.	.005	.040	.066

Conclusion: U_{NDC} U_{SDC}
$1\#_{NDC}$ $1\#_{SDC}$
$2\#_{NDC}$ $2\#_{SDC}$

8 Years

NDC	$\bar{x}$	1.137	1.193	1.200
	s.d.	.130	.182	.163
	s.e.	.033	.041	.041
SDC	$\bar{x}$	1.449	1.549	1.542
	s.d.	.073	.061	.079
	s.e.	.037	.030	.040

Conclusion: U_{NDC} U_{SDC}
$1\#_{NDC}$ $1\#_{SDC}$
$2\#_{NDC}$ $2\#_{SDC}$

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